

CLAIMS

1. A thin-film piezo-resonator comprising:

5 a substrate having a first surface and a second surface opposite to said first surface, the substrate being formed with a cavity that has a first opening in said first surface and a second opening in said second surface; and

10 a resonator assembly including an exciter composed of a first electrode contacting said first surface, a piezoelectric layer on the first electrode and a second electrode on the piezoelectric layer, the assembly being disposed at a location corresponding to the cavity;

15 wherein the cavity includes a side surface extending in a substantially perpendicular direction to said first surface.

2. The resonator according to Claim 1, wherein the first electrode comprises a uniaxially oriented single-layer
20 conductive member or uniaxially oriented multi-layer conductive member.

3. The resonator according to Claim 2, wherein the piezoelectric layer is uniaxially oriented.

25 4. The resonator according to Claim 1, wherein the substrate is a (111)-cut silicon substrate, said first

surface and said second surface each being a (111) surface.

5. The resonator according to Claim 4, wherein the first electrode comprises a single conductive layer containing either one of (111)-uniaxially oriented Al and (111)-uniaxially oriented Cu.

6. The resonator according to Claim 4, wherein the first electrode comprises a stack of uniaxially oriented conductive layers including a first conductive layer held in contact with said first surface, the first conductive layer containing either one of (111)-uniaxially oriented Al and (111)-uniaxially oriented Cu.

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7. The resonator according to Claim 4, wherein the first electrode has a two-layer structure comprising a first conductive layer and a second conductive layer, the first conductive layer held in contact with said first surface and containing either one of (111)-uniaxially oriented Al and (111)-uniaxially oriented Cu, the second conductive layer containing (110)-uniaxially oriented Mo.

8. The resonator according to Claim 4, wherein the piezoelectric layer is made of either one of (002)-uniaxially oriented AlN and (002)-uniaxially oriented ZnO.

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9. The resonator according to Claim 1, further comprising a cover substrate bonded to said second surface of the substrate so as to close the cavity.

5 10. The resonator according to Claim 1, wherein each of the first and the second openings has a circular or oval configuration.

11. The resonator according to Claim 1, wherein each of
10 the first electrode and the piezoelectric layer includes a portion exposed to the cavity.

12. The resonator according to Claim 11, wherein the exposed portion of the first electrode and the exposed
15 portion of the piezoelectric layer are made of a material which is not etched by a fluorine gas.

13. A thin-film piezo-resonator comprising:
a (111)-cut silicon substrate;
20 a first electrode formed on the substrate and containing either one of Al and Cu;
a piezoelectric layer formed on the first electrode and containing either one of AlN and ZnO; and
a second electrode formed on the piezoelectric
25 layer;

wherein the silicon substrate includes a first surface which is a (111) surface, the first electrode being held in contact with said first surface.

5 14. A thin-film piezo-resonator comprising:

a substrate having a first surface and a second surface opposite to said first surface, the substrate being formed with a cavity that has a first opening in said first surface; and

10 a resonator assembly including a first electrode contacting said first surface, a piezoelectric layer on the first electrode and a second electrode on the piezoelectric layer, the assembly being disposed at a location corresponding to the cavity;

15 wherein each of the first electrode and the piezoelectric layer includes a portion exposed to the cavity.

15. The resonator according to Claim 1, wherein the first
20 and the second electrodes comprise first and second exciter portions, respectively, that define the exciter, the first opening being greater in area than the exciter portions by a factor of 1~2.25.

25 16. The resonator according to Claim 15, wherein the first exciter portion and the second exciter portion are substantially identical in shape.

17. The resonator according to Claim 15, wherein each of the first and the second exciter portions is at least partially circular or oval.

5 18. A filter comprising:

a substrate having a first surface and a second surface opposite to said first surface, the substrate being formed with a plurality of cavities spaced from each other;

10 a first electrode pattern held in contact with said first surface;

a piezoelectric layer on the first electrode pattern;

15 a second electrode pattern on the piezoelectric layer; and

a plurality of resonator assemblies provided by a combination of the first electrode pattern, the piezoelectric layer and the second electrode pattern, each of the resonator assemblies corresponding in position to one of the cavities;

20 wherein each of the cavities has a side surface extending in a substantially perpendicular direction to said first surface.

25 19. The filter according to Claim 18, wherein each of the cavities includes a first opening in said first surface and a second opening in said second surface, a distance

between adjoining first openings being no greater than 420 μm .

20. The filter according to Claim 18, wherein said
5 plurality of resonator assemblies include a first group of resonator assemblies connected in series and a second group of resonator assemblies connected in parallel.

21. The filter according to Claim 18, wherein the first
10 electrode pattern and the piezoelectric layer are exposed to one of the cavities.

22. A filter comprising:

15 a substrate having a first surface and a second surface opposite to said first surface, the substrate being formed with a plurality of cavities each including a first opening in said first surface and a second opening in said second surface;

20 a first electrode pattern held in contact with said first surface;

a piezoelectric layer on the first electrode pattern;

a second electrode pattern on the piezoelectric layer; and

25 a plurality of exciters provided by a combination of the first electrode pattern, the piezoelectric layer and

the second electrode pattern, each of the exciters corresponding in position to one of the cavities;

wherein the first electrode pattern and the piezoelectric layer each include a portion exposed to one
5 of the cavities.

23. The filter according to Claim 22, wherein the exposed portions of the first electrode pattern and the piezoelectric layer are made of a material which is not
10 etched by a fluorine gas.

24. The filter according to Claim 22, wherein each of the exciters is defined by a first exciter portion and a second exciter portion contained respectively in the
15 first electrode pattern and the second electrode pattern, the first exciter portion and the second exciter portion being substantially identical in shape.

25. The filter according to Claim 24, wherein the first
20 opening of the cavity corresponding to said each exciter is greater in area than the exciter portions by a factor of 1~2.25.

26. The filter according to Claim 22, wherein the first
25 and the second openings of each cavity are circular or oval.

27. A method of making a thin-film piezo-resonator comprising steps of:

preparing a substrate including a first surface and a second surface opposite to said first surface;

5 forming a resonator assembly which includes a first electrode held in contact with said first surface, a piezoelectric layer formed on the first electrode and a second electrode formed on the piezoelectric layer; and

10 forming a cavity by dry-etching the substrate, the cavity being disposed at a location corresponding to the resonator assembly, the cavity being opened in said first surface and said second surface;

15 wherein the cavity includes a side surface extending in a substantially perpendicular direction to said first surface.

28. The method according to Claim 27, wherein the dry etching is Deep-RIE.

20 29. The method according to Claim 27, further comprising the step of bonding a cover substrate to said second surface so as to close the cavity.

25 30. The method according to Claim 27, wherein a groove for dividing the substrate is also formed by etching at the cavity-forming step.

31. A method of making a thin-film piezo-resonator comprising steps of:

preparing a substrate including a first surface and a second surface opposite to said first surface;

5 forming a resonator assembly which includes a first electrode held in contact with said first surface, a piezoelectric layer formed on the first electrode and a second electrode formed on the piezoelectric layer; and

10 forming a cavity by dry-etching the substrate, the cavity being disposed at a location corresponding to the resonator assembly, the cavity being opened in said first surface and said second surface;

15 wherein the first electrode and the piezoelectric layer are partially exposed to the cavity at the cavity-forming step.